UNIVERSITY OF DENVER
DENVER RESEARCH INSTITUTE
Denver, Colorado

Semi-Annual Report

Bubble Growth Parameters in Saturated and Subcooled Nucleate Boiling

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APPROVED BY:

Rodney F. Recht
Head, Mechanics Division

SUBMITTED BY:

Thomas R. Rehm
Project Supervisor

I. INTRODUCTION

This semi-annual report is concerned with a research program sponsored by the National Aeronautics and Space Administration through its Lewis Research Center in Cleveland, Ohio. The program is divided into two sections, one dealing with the obtaining of boiling parameters for fluids other than water, and the other dealing with photographic observation of the initial growth of bubbles under boiling conditions.

II. STATUS OF THE PROGRAM

Since the initiation of this program in December of 1965, the technical portion of the research has been confined to Section A of the program. Section A deals with the observation of bubble growth parameters in fluids having physical properties different than water.

A. Experimental

The experimental portion of Section A has essentially been completed; this is, sufficient photographic data appear to have been obtained to realize the desired objectives.

The heater apparatus used in a previous research program carried out under NASA Grant NsG-143-61, Supplement No. 1, was used to obtain photographic data at 7500 to 8000 pictures per second. Since the heater had not been used for some months, and it was felt that the condition of the heater surface might have changed during this time, a series of twelve data runs using distilled and degassed water at a heat flux of 50,000 Btu/hr/ft^2 was made as a basis for comparison with the runs made with other fluids. Selected bubbles from these water runs were analyzed and compared with bubbles obtained previously. The comparisons were satisfactory.

The first set of non-water runs were with aqueous solutions of sucrose. The concentration was nominally 60 weight percent sucrose in water. The actual solutions varied from 60.7 to 62.5 weight percent sucrose in distilled water. Concentrations were determined by refractive index methods. Four runs at a heat flux of 50,000 Btu/hr/ft^2, one each, at a subcooling of 1.5, 11.7, 21.4, and 31.4 F$^\circ$ were obtained from which at least two bubbles for each run were suitable for growth analysis. Four runs at essentially a 100,000 Btu/hr/ft^2 heat flux were made at similar subcoolings, again with many suitable bubbles being obtained.

The use of the sucrose solution permitted the study of the influence of viscosity on boiling. At boiling temperatures, the sucrose solution had a viscosity of 4.4 centipoise, some 14 times that of water. The density and surface tension of the sucrose were only slightly different than those for water.

The second non-water fluid used was a solution of one weight percent n-propanol in water. The particular property of this solution is its low value of surface tension, being approximately 20 dynes/cm at the boiling point whereas pure water has a value some three times greater. The viscosity and density were assumed to be the same as for pure water.

Four runs at a heat flux of 50,000 Btu/hr/ft^2 and four runs at 100,000 Btu/hr/ft^2 were obtained at subcoolings of the order of zero, 10, 20, and 30 F$^\circ$. Bubbles suitable for analysis were obtained from all runs.

The runs with these two fluids should adequately determine the influence of surface tension and viscosity variations on bubble growth.

B. Data Analysis

The frame-by-frame analysis of the bubbles obtained is being done in a more precise manner than that used in previous work carried out in this laboratory. Bubble photographs are inspected at some 50X magnification; selected bubbles are then traced as to their outlines on millimeter graduated graph paper. The bubble volume is then determined by summing up the volume of a number of circular discs. The actual arithmetic steps are carried out on a Burroughs B-5500 digital computer. The computer program also determines the value of the center of mass of the bubble. The center of mass position, h, is then fitted to a curve so that h can be expressed as a function of bubble life time, Θ. In the first rapid growth period, comprising some 10 to 15 percent of the bubble life time between initiation and separation, the curve has an equation of the form:

$$h = a\Theta^b$$

where a and b are constants evaluated for each bubble. For the remainder of the bubble life time, the curve has the form of:

$$h = C + D(\Theta) - E(\Theta)^2$$

i.e., that of a three-term polynomial. The use of equations of this type will permit much easier determination of bubble velocity and acceleration, both of which are needed in the evaluation of the bubble forces. In addition, the constants in these equations can be used to correlate the bubbles as to the influence of liquid and heater conditions on the bubble behavior. Some 40 bubbles are currently being analyzed in this way.

III. PROPOSED PROGRESS

With regard to Section A of the research program, the bubbles will be analyzed as mentioned previously and their forces determined. Additional experimental data may be obtained if needed, using an agueous solution of a polysaccharide which produces a fluid having a viscosity some 500 to 1000 times that of water.

The greater proportion of the remaining grant time will be spent on the building of a boiler, gathering of experimental apparatus, and obtaining of photographic data of the initial bubble growth period. At present, it is thought a physical shock technique will be appropriate to initiate bubble growth at a known time in order that photos at some one million frames per second can be obtained satisfactorily.